FACIAL SINUS ENDOSCOPIC EVALUATION, RADIOLOGIC ASSESSMENT AND CLASSIFICATION

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Conflict of Interest

The authors declare no conflict of interest.

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ABSTRACT

Objectives: To describe facial sinus anatomy from an endoscopic perspective and to present a radiologic classification.

Methods: Facial sinus was studied by endoscopy and high resolution computed tomography (HRCT) scan in 39 temporal bones which underwent exclusive transcanal endoscopic approach. A radiomorphologic classification, based on the relationship between the facial sinus and the mastoid portion of the facial nerve is created as follows. In type A the pneumatization of facial sinus did not extend medially nor posteriorly to the mastoid portion of facial nerve. In type B facial sinus the pneumatization extended posteriorly to the mastoid portion of facial nerve. In type C facial sinus the pneumatization extended posteriorly and medially to the mastoid portion of facial nerve.

Results: In all the specimens which underwent HRCT (n=31) facial sinus could be identified and its depth could be classified in relationship to facial nerve. In this group 58% type A, 29% type B and 13% type C facial sinuses were identified. In all the specimens (n=39) the facial sinus could be assessed by means of an exclusive endoscopic transcanal approach and anatomical variants of the *chordiculus* could be described: ridge (39%), bridge (18%), incomplete (15%) and absent (28%).

Conclusion: Endoscopic exploration of the retrotympanum guarantees a very good exposure of the facial sinus, allowing detailed anatomic descriptions of its conformation and relationships with other structures. Improvement in our knowledge of its anatomy might decrease the possibility of residual disease during cholesteatoma surgery. Angled endoscopes (e.g. 45°, 70°) can guarantee a better view of facial sinus.

Keywords: facial sinus; lateral tympanic sinus; transcanal endoscopic approach; retrotympanum; middle ear; chordiculus; radiologic classification

Level of Evidence: NA

INTRODUCTION

In the recent literature, present authors have already studied the endoscopic and radiologic anatomy of the retrotympanum[1], describing the variations in shape and relationship of the sinus tympani[2,3], the pyramidal eminence with the subpyramidal space[4] and the round window niche[5].

However, until now no studies have focused on the endoscopic anatomy of the facial sinus (FS), and its relationship with surrounding structures.

FS was probably described for the first time in 1888 by Sappey[6] and for this reason it was also known as the *suprapyramidal fossa of Sappey*. The FS is an area superolateral to the pyramidal eminence bounded by the posterior edge of the bony annulus laterally, the fossa incudis superiorly, the third tract of the facial nerve (FN) medially and an inconstant bony ridge inferiorly, named chordal ridge, which runs from the roof of the pyramidal eminence toward the chordal eminence, where the chorda tympani enters to the tympanic cavity. This latter anatomical landmark divides the FS from the lateral tympanic sinus (LTS), also known as *fossa of Grivot*[7], placed inferiorly compared to FS. Since then, the FS has been described from a microscopic point of view mainly because it represents the route used in posterior tympanotomy which allows the access to the tympanic cavity and the round window area (Fig. 1).

In the last decade, there has been a growing interest regarding the transcanal endoscopic ear surgery (TEES), a technique that allows the management middle ear disease, such as cholesteatoma, with no external incisions, minimal morbidity for patient, short hospital stay and low complications rate[8]. As mentioned above, the endoscopic view improves the visualization of the retrotympanum and its recesses, like the posterior tympanic sinus (PTS), the sinus tympani (ST) and sinus subtympanicus[1]. However, an endoscopic description and analysis of the FS and its topographic relationships is still lacking in the literature.

The aim of our study is to analyze and revisit the morphology and the anatomic variations of the facial sinus from an endoscopic and radiologic point of view, trying to produce an easy and fast classification, such as the one already proposed for the ST[3]. The present authors consider that these

descriptions could be important for ear surgeons, because a thorough assessment of this space could have consequences on clinical and surgical practice.

MATERIALS AND METHODS

From January 2017 to July 2017, 39 temporal bones were prospectively included in our study. Of these, 31 specimens previously underwent a high-resolution computed tomography (HRCT). Axial projections were obtained with sequential 1.0-mm slices; scanning was performed from the arcuate eminence to the jugular fossa. The variation in depth of the FS and ST areas were assessed, analyzing the posterior and medial extension of the medial boundary of the FS and ST with respect to the mastoid portion of the FN. A radiomorphologic classification of the FS was created (Fig. 2-3; Table 1) in a similar fashion of that already introduced for ST[2,3] . Thus, the depth of each FS was classified based upon the relationship to facial nerve.

Later, all the specimens (n=39) underwent endoscopic dissection by means of an exclusive transcanal approach.

The equipment used during dissection was of 3-mm diameter, 15-cm length, 0° and 45° rigid Hopkins rod telescopes and 4-mm diameter, 15-cm length, 70° rigid Hopkins rod telescope (Karl Storz, Tuttlingen, Germany). A three-chip high-resolution monitor and camera (Karl Storz, Tuttligen, Germany) were used for all the procedures. A set of angled instruments was used for all the surgical steps. The transcanal approach consisted of the elevation of the tympanomeatal flap to access the middle ear cleft and the exploration of the superior retrotympanum was performed as already described in earlier papers[3]. The exploration of the recesses of the superior retrotympanum required prior cleaning and removal of mucosal folds with angled instruments. The anatomy was documented photographically and reviewed by the authors.

The data were summarized in appropriate database. Descriptive statistics were performed with Microsoft Excel, 15.33 version®.

RESULTS

Radiologic findings

In all the specimens (n=31 temporal bones) which had a HRCT scan, radiologic conformation of the FS and the ST could be classified by evaluating the relationship with the mastoid portion of the facial nerve in CT scan-axial plane.

Based on our classification of the FS, it was found that 18/31 (58%) temporal bones had a radiologic morphology type A; 9/31 (29%) had a radiologic morphology type B; 4/31 (13%) had a radiological morphology type C (Fig. 2-3).

Regarding the ST, the radiologic morphology was assessed by the criteria already described in literature[2]. It was found that 14/31 (45%) temporal bones had a radiologic morphology type A; 15/31 (48%) had a radiologic morphology type B; 2/31 (7%) had a radiologic morphology type C.

A correspondence of depth (e.g. FS type A and ST type A) in the radiologic morphology of the FS and ST was found in 15/31 (48%) specimens.

Endoscopic findings

In all the specimens (n=39 temporal bones), the FS could be assessed by means of an exclusive transcanal approach. 0° and 45° scopes were used in all the cases, while we could use the 70° only in 33 cases due to its wider outer diameter (4-mm) which could not be handled in case of narrow EAC.

In 34/39 (87%) specimens, the FS appeared as pneumatized and well delimited.

In only 2/39 (5%) the FS could be entirely explored with a 0° scope, while the percentage roses up to 51% (20/39) with a 45° scope. Even if only 33 specimens were studied with the 70° lens, the FS was completely assessed in 27/33 (81%) temporal bones (Fig. 4).

In 28/39 (72%) specimens, a structure arising from the roof of the pyramidal eminence and connected to the chordal eminence was found located at the posterior edge of the bony annulus and

corresponding to the entrance of the chorda tympani into the middle ear cavity. This structure represented the limit between the LTS and the FS, as mentioned. Former authors, named that structure chordal ridge[6],[7]. Actually, some variations in morphology of the chordal ridge were noticed. In 15/39 (39%) cases it was like a ridge of bone, but in 7/39 (18%) it was bridge-shaped and in 6/39 (15%) it was incomplete or absent (11/39-28%) (Fig. 5). Due to these results about anatomic variability, especially the presence of a significant percentage of bridge-shaped chordal ridge, present authors deemed appropriate to re-name it as *chordiculus.* This denomination would also help in making the nomenclature of retrotympanic structures uniform.

Eventually, the FS had two kind of anatomic conformation:

- Classic shape (15/39 – 39%): the sinus was located between the lateral semicircular canal and *chordiculus,* lying lateral to the FN
- Confluent shape (24/39 – 61%): an incomplete or bridge *chordiculus* was present and the FS was confluent to the LTS

Radiologic – Endoscopic correlation

The endoscopic assessment of all the temporal bones was matched with the radiomorphologic classification.

Of the 18 type A facial sinuses, 11/18 (61%) could be totally explored by means of a 45° scope and 17/18 (94%) by a 70° scope. On the other hand, no one could be assessed by a 0° scope.

Of the 9 type B facial sinuses, 6/9 (67%) could be totally explored by means of a 70° scope, while only 1/9 (11%) by a 45° lens and no one by 0° endoscope.

Of the 4 type C facial sinuses, 1/4 (25%) could be evaluated by 70° lens and by the 45° lens, while no one was entirely visualized with the 0° endoscope.

DISCUSSION

The retrotympanum is one of the most variable areas of the middle ear cleft. In literature, several authors have already studied the anatomy of this region. In particular, present authors have already described from an endoscopic perspective the ST[2,3], the pyramidal eminence with the subpyramidal space[4], the sinus subtimpanicus and the round window niche[9] with the subcochlear canaliculus[5]. In 1969 Proctor had already described the microscopic surgical anatomy of the posterior tympanic wall and defined a system of sinuses around several permanent projections of the styloid complex, such as the pyramidal eminence, the styloid eminence and the chordal eminence[10]. The sinuses of the retrotympanum were: sinus tympani and posterior tympanic sinus (laying medial to the facial nerve), and lateral tympanic sinus and facial sinus (laying lateral to the facial nerve).

In 1888 Sappey was probably one of the first to describe FS. He named it as *suprapyramidal fossa*, due to its position in relation to the pyramidal emincence[6]. Nowadays some authors still refers to him by naming the biggest cell of the pneumatization of the FS as *suprapyramidal fossula of Sappey*[11].

Former authors [6,7]described an inconstant bony ridge inferiorly to FS, running from the roof of the pyramidal eminence toward the chordal eminence, where the chorda tympani enters the tympanic cavity. This structure was previously named chordal ridge. Based on the results of our study, a bridge shaped morphology was identified in 7/39 (18%) specimens. Indeed, to the best of present authors knowledge, this is the first time that such anatomic variation is described. Thus, the term chordal ridge would be inappropriate in a relevant percentage of cases. For this reason, the term *chordiculus* is herein introduced, also according to universally accepted nomenclature used to describe other retrotympanic structures.

As mentioned above, several authors described this area from a microscopic point of view, as it represents the access to the middle ear cavity through the posterior tympanotomy in transmastoid route. Parlier-Cuau et al. conducted a radiologic study based on 66 disease free temporal bones CT scans studying several retrotympanic structures, among which there were also the LTS, FS and ST. Radiologic detection of all these landmarks was variable. The *chordiculus* was detected in 52%, ST

in 95% of cases and FS in 80% of the specimens. In axial sections the FS appeared pneumatized in 41% and it was reported that its average depth was 2.2 mm[12].

Cheiţă A.C. et al., in a study based on anterior dissections of 37 temporal bones, demonstrated how variable is the anatomy of the retro-tympanum, underlining that the presence of the all four recesses is not a rule and that variability in size, shape and internal configuration is very common. They found that the depth of the FS ranged from 1.45 to 3.11 mm (with an average depth of 2.28 mm) and also proposed a classification of the FS based upon its internal configuration of pneumatized cells[11]. Since the classification system proposed by Cheiţă A.C. et al. is based upon presence and shape of air cells inside FS, this kind of description has in present authors opinion little impact on surgical attitude. For that reason we decided to classify FS in a way that could have direct consequences on surgery, because the depth of FS could influence its endoscopic visualization, in particular by angled optics.

Williamson et al. assessed the width of the facial recess during cochlear implant approaches and reviewed the data in the literature (97 cases) demonstrating that a diameter of 2.54 +/- 0.5 mm can be accepted as representative[13].

Since the introduction of the endoscope in otologic field, middle ear anatomy has been revisited. In fact, some anatomical structures that had been neglected simply because they were hardly visualized by microscopic approach, have been carefully explored and described. In particular, retrotympanum has been widely studied and described in several published papers. Probably such an interest is focused on this area of the middle ear because its microscope-based exploration is tricky and that is why it has always been considered as a "blind-spot" for microscopic otosurgical approaches. Nevertheless, many effort has been done to find a way to improve the surgical exposure of this region[14–17]. Moreover, several authors have already shown how common is the residual cholesteatoma in this area and its subsites[18,19] which is probably due to poor visualization of traditional approaches that cannot permit complete removal of cholesteatoma matrix. Thomassin et al. found that the completeness of disease eradication had significantly improved by the endoscope[20]. Later on, several other authors confirmed that TEES offered a suitable access to various middle ear

lesions, determining a significant reduction in frequency of open tympanoplasties and recourse to posterior tympanotomy[18,19,21,22].

Present study shows that endoscopic exploration of the lateral recesses of the retrotympanum is feasible and allows thorough assessment of all their subsites and relationship with adjacent structures (e.g. mastoid portion of FN, lateral semicircular canal, chorda tympani) by means of angled scopes. In fact, in only 2/39 (5%) the FS could be entirely explored with a 0° scope, while the percentage roses up to 51% with the 45° scope and 81% with the 70° scope.

Moreover, high-resolution 1-mm slices CT scan can predict which scope could fit better to entirely assess the depth of the FS. More than the half of the type A FS could be assessed by a 45° scope, even if 94% type A and 67% type B FS were perfectly explored with a 70° scope. Given the rarity of FS type C (2/31) and the small group of specimens studied, further studies should be made to confirm our results.

In author's opinion, knowledge of the FS can be important for otosurgeons, especially during surgery for cholesteatoma. In fact, the FS could potentially harbor residual cholesteatoma matrix, especially if the space is very deep and its exposure is not easy. For this reason, present authors would recommend endoscopic exploration of this region in case of its suspected involvement. Moreover, an adequate and detailed knowledge of the retrotympanic spaces could help in reducing iatrogenic damages to the facial nerve.

CONCLUSION

FS can be explored by endoscopic approaches to middle ear. Angled optics (45° and 70°) may be necessary to completely visualize this space, particularly for deeper sinuses, and should be used systematically. FS can be radiologically classified in type A, B and C, based on its relationship to mastoid tract of FN, just in the same way previously described for ST. *Chordiculus* can have different shapes (ridge, bridge) and can be incomplete or absent. The shape of *chordiculus* can influence the

different conformations that FS can have (e.g. normal, confluent). In author's opinion anatomic knowledge and right interpretation of radiologic aspect of FS may have clinical consequence in reducing residual cholesteatoma and could potentially reduce the risk of damages to the facial nerve.

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FIGURE AND TABLE LEGENDS

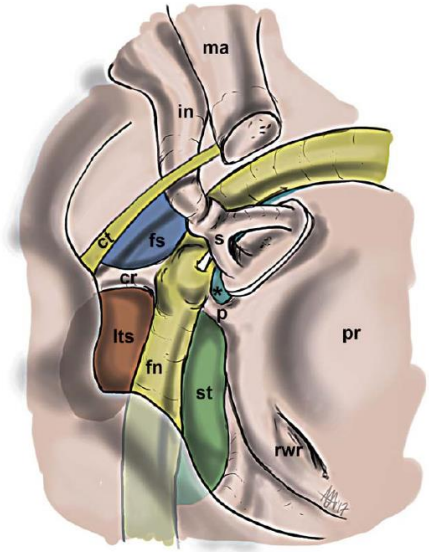

Figure 1. Right ear. Drawing representing the medial and lateral spaces of retrotympanum. Anatomic boundaries of facial sinus are here clarified. pr, promontory; rwr, round window region; s, stapes; *, posterior sinus; p, ponticulus; st, sinus tympani; fn, facial nerve; fs, facial sinus; cr, chordiculus; lts, lateral tympanic sinus; ct, chorda tympani; in, incus; ma, malleus.

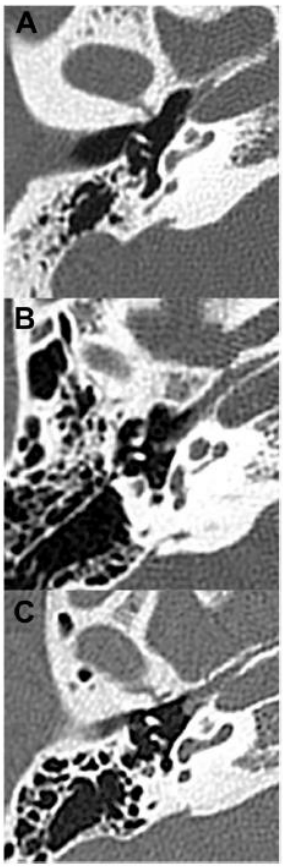

Figure 2. Radiomorphologic evaluation of the depth and extension of the facial sinus (FS), in relationship to the mastoid portion of facial nerve (based on axial CT scan, right ear). Panel A. small FS. Panel B. deep FS with posterior extension. Panel C. very deep FS with medial and posterior extension. Black arrow indicates the third portion of the facial nerve.

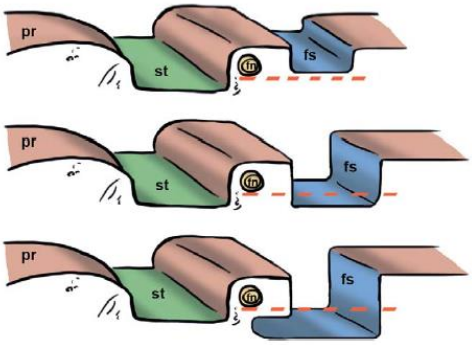

Figure 3. Classification of the depth of the facial sinus (FS). Panel A. FS Type A; small FS without medial and posterior extension with respect to the mastoid portion of facial nerve (FN). Panel B. FS Type B; FS with posterior extension and without medial extension with respect to the mastoid portion of FN. FS Type C; FS with medial and posterior extension with respect to the mastoid portion of FN. Pr, promontory; st, sinus tympani; fn, facial nerve; fs, facial sinus.

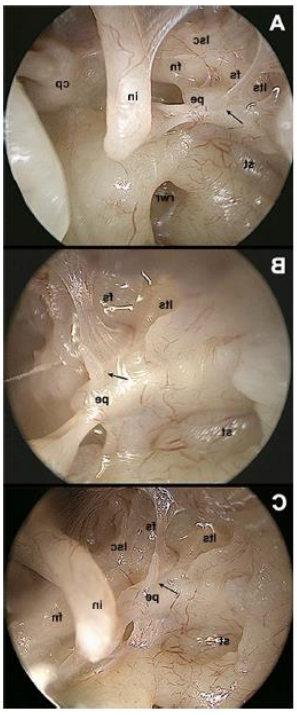

Figure 4. Endoscopic assessment of the FS with different angled lenses. Panel A. 0° endoscope. Panel B. 45° endoscope. Panel C. 70° endoscope (fundus of the FS can be entirely visualized).

Pe, pyramidal eminence; fn, facial nerve; lsc, lateral semicircular canal; fs, facial sinus; lts, lateral tympanic sinus; st, sinus tympani; rwr, round window region; in, incus; cp, choclearifom process. Black arrow indicates an incomplete chordiculus.

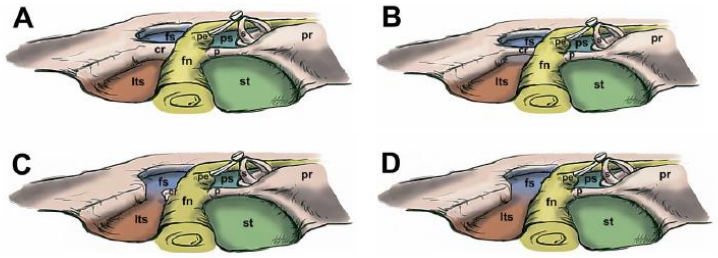

Figure 5. Sample drawing showing the morphological variations of the chordiculus. The presence and the type of the chordiculus influences the shape of the FS (classic vs confluent). Panel A. Ridge chordiculus and classic shape FS. Panel B. Bridge chordiculus and confluent shape of FS. Panel C. Incomplete chordiculus and confluent shape of FS. Panel D. Absent chordiculus and confluent shape of FS. Lts, lateral tympanic sinus; fs, facial sinus; st, sinus tympani; ps, posterior sinus; fn, facial nerve; p, ponticulus; cr, chordiculus; pe, pyramidal eminence; pr, promontory; s, stapes.

TABLE I.
Radiomorphologic classification of facial sinus

	Facial Sinus	Pneumatization of Facial Sinus
Type A	Small	Not beyond the mastoid tract of facial nerve
Type B	Deep	Posteriorly to mastoid tract of facial nerve
Type C	Very deep	Posteriorly and medially to the mastoid tract of facial nerve